In accordance with another embodiment of the present invention, a second sensing coil is used for stabilization purposes. Inaccurate readings of the catheter probe location may occur from motion artifacts due to breathing action, heart motion, or patient movement. The stabilized location coordinates may be determined by placing a second sensing coil on the sternum of the patient at a known location within the navigational domain. The incremental movement experienced by the second sensing coil due to motion artifacts is detected and subtracted from the measured location value of the probe to arrive at the actual location coordinates of the probe. Further extensions of the present invention are possible to facilitate multi-catheter applications by attaching an additional sensing coil to the distal end of each additional catheter.

Since certain changes may be made in the above apparatus and method without departing from the scope of the invention herein described, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted in an illustrative and not in a limiting sense.

What is claimed is:

1. A method of determining the location of a magnetically-sensitive, electrically conductive sensing coil affixed to a distal end of a catheter probe partially inserted into a body cavity within a navigational domain, comprising the steps of:

inducing within said sensing coil a set of orientation signal values each representative of an orientation of said sensing coil and independent of a position of said sensing coil;

determining the orientation of said sensing coil using said induced orientation signal values;

inducing within said sensing coil a set of positional signal values each representative of the position of said sensing coil; and

determining the position of said sensing coil using said positional signal values and said determined orientation.

2. The method as recited in claim 1, wherein the step of inducing said set of orientation signal values comprises the steps of:

generating from outside said body a series of magnetic fields each penetrating at least said navigational domain and characterized substantially by a principal magnetic component in one axial dimension and relatively smaller magnetic components in two other axial dimensions.

3. The method as recited in claim 1, wherein the step of inducing said set of positional signal values comprises the steps of:

generating from outside said body a series of magnetic fields each penetrating at least said navigational domain and characterized substantially by two principal gradient magnetic components in respective axial dimensions and a relatively smaller magnetic components in a third axial dimension.

4. The method as recited in claim 3, wherein said generating step further includes the steps of:

generating said fields to provide a plurality of constant signal surfaces for the sensing coil such that an intersection between two such surfaces with components in the same axial dimensions produces a line along which said sensing coil is located;

wherein said two such surfaces are identified from among said plurality of constant signal surfaces by their ability to induce one of said positional signal values.

5. The method as recited in claim 4, further comprises the steps of:

weighting each line in accordance with a signal strength of said corresponding constant signal surface; and

determining an intersection of said weighted lines.

6. The method as recited in claim 5, wherein six constant signal surfaces are generated to produce three intersection lines.

7. A system for determining the location of a magnetically-sensitive, electrically conductive sensing coil affixed to a distal end of a catheter probe partially inserted into a body cavity within a navigational domain, comprising:

first transmit means for projecting into said navigational domain magnetic energy that is sufficient to induce signal values within said sensing coil representative of an orientation of said sensing coil and independent of the position of said sensing coil;

second transmit means for projecting into said navigational domain magnetic energy that is sufficient to induce signal values within said sensing coil representative of the position of said sensing coil; and

analysis means, coupled to said first transmit means and said second transmit means, for determining the position and orientation of said sensing coil from said induced signal values.

8. A system for determining the location of a magnetically-sensitive, electrically conductive sensing coil affixed to a distal end of a catheter probe partially inserted into a body cavity within a navigational domain, comprising:

first signal-inducing means for inducing within said sensing coil orientation signals that are representative of the orientation of said sensing coil;

analysis means, coupled to said first signal-inducing means, for determining the orientation of said sensing coil using said induced orientation signals and independent from a position of said sensing coil;

second signal-inducing means for inducing within said sensing coil position signals that are representative of the position of said sensing coil; and

analysis means, coupled to said second signal-inducing means, for determining the position of said sensing coil using said determined orientation and said induced position signals.

9. The system as recited in claim 8, wherein the first signal-inducing means comprises:

field generation means for successively generating magnetic field patterns projected into said navigational domain, each characterized substantially by a principal magnetic field component in one direction and relatively smaller magnetic components in two other directions.

10. The system as recited in claim 9, wherein said field generation means comprises a set of magnetic coils.

11. The system as recited in claim 10, wherein said magnetic coils are disposed in a planar top of an examination deck upon which a patient is disposed during a surgical procedure.

12. The system as recited in claim 10, wherein said magnetic coils are disposed in a planar top and in rail members edge supported by said planar top for an examination deck upon which a patient is disposed during a surgical procedure.

13. The system as recited in claim 8, wherein the second signal-inducing means comprises:

field generation means for successively generating magnetic field patterns each characterized by a first and

second gradient field component in respective directions and a relatively smaller third component in another direction.

14. The system as recited in claim 13, wherein the field generation means comprises a magnetic coil assembly.

15. A method of determining the location of a magnetically-sensitive, electrically conductive sensing coil affixed to a distal end of a catheter probe partially inserted into a body cavity within a navigational domain, comprising the steps of:

defining the location of said sensing coil with a set of independent location parameters; and

sequentially generating within said navigational domain a sequence of magnetic fields for inducing within said sensing coil a corresponding sequence of induced signals each defined by an induced signal expression that functionally relates said induced signal to certain ones of said location parameters, such that said set of location parameters is determinable by sequentially solving individual signal expression groups each including certain ones of said induced signal expressions and sufficient to represent a subset of said location parameters.

16. The method as recited in claim 15, wherein said sequence of magnetic fields comprises:

a series of unidirectional magnetic fields each characterized substantially by a principal magnetic field component in one direction and relatively smaller magnetic components in two other directions; and

a series of gradient magnetic fields each characterized by a first and second gradient field component in respective directions and a relatively smaller third component in another direction.

17. The method as recited in claim 16, wherein said signal expression groups include:

an orientation group including induced signal expressions each functionally related to a respective one of said unidirectional magnetic fields and an orientation of said sensing coil, and independent of a position of said sensing coil; and

a position group including induced signal expressions each functionally related to a respective one of said gradient magnetic fields, the orientation of said sensing coil, and the position of said sensing coil.

18. The method as recited in claim 17, wherein the step of sequentially solving said individual signal expression groups includes the steps of:

initially solving the induced signal expressions of said orientation group; and

next solving the induced signal expressions of said position group.

19. A system for determining the location of a magnetically-sensitive, electrically conductive sensing coil affixed to a distal end of a catheter probe partially inserted into a body cavity within a navigational domain, comprising:

means for defining the location of said sensing coil with a set of independent location parameters; and

field generation means for sequentially generating within said navigational domain a sequence of magnetic fields for inducing within said sensing coil a corresponding sequence of induced signals each defined by an induced signal expression that functionally relates said induced signal to certain ones of said location parameters, such that said set of location parameters is determinable by sequentially solving individual signal expression groups each including certain ones of said induced signal expressions and sufficient to represent a subset of said location parameters.

20. The system as recited in claim 19, wherein said sequence of magnetic fields comprises:

a series of unidirectional magnetic fields each characterized substantially by a principal magnetic field component in one direction and relatively smaller magnetic components in two other directions; and

a series of gradient magnetic fields each characterized by a first and second gradient field component in respective directions and a relatively smaller third component in another direction.

21. The system as recited in claim 20, wherein said signal expression groups include:

an orientation group including induced signal expressions each functionally related to a respective one of said unidirectional magnetic fields and an orientation of said sensing coil, and independent of a position of said sensing coil; and

a position group including induced signal expressions each functionally related to a respective one of said gradient magnetic fields, the orientation of said sensing coil, and the position of said sensing coil.

22. The system as recited in claim 21, wherein said field generation means comprises:

analysis means for solving the induced signal expressions of said orientation group; and

analysis means for solving the induced signal expressions of said position group.

* * * * *

23. A method of determining the location and orientation of at least one magnetically-sensitive, electrically conductive sensing coil affixed to a distal end of a catheter probe partially inserted into a body cavity within a navigational domain, comprising the steps of:

inducing within said at least one sensing coil a set of orientation signal values each representative of an orientation of said at least one sensing coil and independent of a position of said at least one sensing coil;

determining the orientation of said at least one sensing coil using said induced orientation signal values;

inducing within said at least one sensing coil a set of positional signal values each representative of the position of said sensing coil; and

determining the position of said at least one sensing coil using said positional signal values and said determined orientation.

24. A method according to claim 23, wherein said at least one sensing coil is substantially passive, such that a current flowing through said sensing coil derives from ambient magnetic fields.

25. A method of determining the locations of a plurality of magnetically-sensitive, electrically conductive sensing coils, each of said plurality of coils being affixed to a distal end of one of a plurality of catheter probes partially inserted into a body cavity within a navigational domain, comprising the steps of:

inducing within each of said plurality of sensing coils a set of orientation signal values each representative of an orientation of said sensing coil and independent of a position of said sensing coil;

determining the orientation of each of said plurality of sensing coils using said induced orientation signal values;

inducing within each of said plurality of sensing coils a set of positional signal values each representative of the position of said sensing coil; and

determining the position of each of said plurality of sensing coils using said positional signal values and said determined orientation, and thereby determining the position of each of said plurality of catheter probes.

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